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## FEEDING ECOLOGY OF *GILA BORAXOBIUS* (OSTEICHTHYES: CYPRINIDAE) ENDEMIC TO A THERMAL LAKE IN SOUTHEASTERN OREGON<sup>1</sup>

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**ABSTRACT.**—*Gila boraxobius* is a dwarf species of cyprinid endemic to a thermal lake in southeastern Oregon. Despite a relatively depauperate fauna and flora in the lake, 24 food items were found in intestines of *G. boraxobius*. Ten of the 24 foods, including six insects, were of terrestrial origin. The relative importance of food items fluctuated seasonally. Diatoms, chironomid larvae, microcrustaceans, and dipteran adults were the primary foods during spring. In summer, diatoms decreased and terrestrial insects increased in importance. During autumn important foods were terrestrial insects, chironomid larvae, and diatoms. Diatoms and microcrustaceans increased in importance during winter. Chironomid larvae were of importance in winter, when the importance of terrestrial food items decreased substantially. Similar food habits were observed between juveniles and adults, except that adults consumed more gastropods and diatoms and juveniles consumed more copepods and terrestrial insects. *Gila boraxobius* feeds opportunistically with individuals commonly containing mostly one food item. Fish typically feed by picking foods from soft bottom sediments or from rocks. However, fish will feed throughout the water column or on the surface if food is abundant there. *Gila boraxobius* feeds throughout the day, with a peak in feeding activity just after sunset. A daily ration of 11.1 percent body weight was calculated for the species during June. A comparison of food habits among *G. boraxobius* and populations of *G. alvordensis* during the summer shows that all are opportunistic in feeding, but that *G. boraxobius* relies more heavily on terrestrial foods.

The Borax Lake chub, *Gila boraxobius*, is a rare species of cyprinid fish endemic to a thermal lake in the Alvord Basin of southeastern Oregon. The restricted habitat of *G. boraxobius* is threatened by geothermal energy development in the Alvord. In recognition of this problem, the species is listed as "threatened" by the Endangered Species Committee of the American Fisheries Society (Deacon et al. 1979) and is currently on the protected list of the Oregon Department of Fish and Wildlife.

*Gila boraxobius* was recently described and has been diagnosed as a dwarf relative of *G. alvordensis* (Williams and Bond, in press). Typical adult size of *Gila boraxobius* is 33–50 mm standard length (SL). Individuals longer than 55 mm SL are rare.

Because no life history information was

known concerning this species, a study was conducted to determine its food habits relative to seasons, fish length, diel feeding chronology, and food habits of other Alvord Basin fishes of the genus *Gila*.

### METHODS

Feeding ecology of *Gila boraxobius* was investigated by analyzing intestinal contents of fish collected monthly from March 1978 to June 1979. Fish were collected from the southwest one-quarter of Borax Lake using a 3 × 5 mm mesh seine approximately 3 m in length. Specimens were preserved in 10 percent formalin and transferred to 45 percent isopropanol after one week. Standard length of specimens was measured to the nearest 0.1 mm with dial calipers. After blotting fish dry on paper towels, wet weight was measured to

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the nearest 0.01 g. *Gila boraxobius*, like other cyprinids, has no stomach; therefore, contents of the intestine, from esophagus to anus, were removed and examined under dissecting microscopes. Percent frequency of occurrence, mean number per intestine, mean percent volume, and a value of relative importance are reported for each food item. Percent frequency of occurrence is defined as the number of intestine samples in which one or more of a given food item is found expressed as a percentage of all nonempty intestines examined (Windell and Bowen 1978). The total number of a given food item observed in the intestines divided by the number of nonempty intestines examined is the mean number per intestine. Mean percent volume is defined as the total volume estimates for a given food item divided by the number of nonempty intestines examined. Percent volumes were derived by separating the intestine into three subsamples and visually estimating the percent contribution of a given food item in each sample. The percent contribution of each subsample to the contents of the entire intestine was estimated so that the volume of a given food item relative to all intestinal contents could be made. Percent frequency of occurrence, mean number per intestine, and mean percent volume each contain a bias which limits their usefulness when used separately (Windell and Bowen 1978). For example, percent frequency of occurrence overemphasizes the importance of small food items that may be ingested frequently but have a small impact on the volume of food in the intestine. On the other hand, mean percent volume overemphasizes the importance of large food items, such as adult insects, that may be consumed infrequently but have a large volume. To offset these biases against each other, an index of relative importance (RI) is reported for each food item. The relative importance index combines the percent frequency of occurrence and mean percent volume for food item *a* into an absolute importance index ( $AI_a$ ) as follows:

$$AI_a = \frac{\text{percent frequency of occurrence} + \text{mean percent volume}}{2}$$

$$RI_a = 100 AI_a / \sum_{a=1}^n AI_a, \text{ where } n \text{ is the number}$$

of different food items. The determination of  $RI_a$  and  $AI_a$  are by methods modified from George and Hadley (1979).

Invertebrate identification was based on Pennak (1978).

Food habits of *G. boraxobius* are summarized as follows: (1) seasonal variation of foods consumed, (2) foods consumed by different size classes of fish, (3) diel feeding chronology, and (4) comparison with food habits of two populations of *Gila alvordensis*. Changes in food habits with season and fish size class were determined from monthly collections taken from March 1978 through January 1979. Monthly collections were grouped into seasons as follows: spring (March–May), summer (June–August), autumn (September–November) and winter (December–January). To compare changes in food habits with fish size, two size classes of fish were compared, 15.0 mm to 32.9 mm SL (juveniles), and 33.0 mm SL or longer (adults). *Gila boraxobius* matures at approximately 33.0 mm SL (Williams and Bond, in press). Diel feeding chronology was determined from collections made at 3-hour intervals during a 24-hour period in June 1979. Fullness of the intestine was determined according to the formula defined by Hureau (1969 in Berg 1979) as follows:

$$Ir = \frac{\text{weight of ingested food} \times 100 \text{ percent}}{\text{weight of fish}}$$

( $Ir$  = L'indice de repletion = fullness index). The daily ration of food for *G. boraxobius* was estimated from diel trajectories of the fullness of the intestine. This estimate was derived by the following formula proposed by Bajkov (1935) and modified by Darnell and Meierotto (1962) and Eggers (1977):

$$R_T = 24\bar{S}\alpha$$

where  $R_T$  is the daily ration,  $\bar{S}$  is the average weight of intestinal contents expressed as percent of body weight during the 24-hour period, and  $\alpha$  is the intestinal evacuation rate. An intestinal evacuation rate of 0.2 hr<sup>-1</sup> is assumed (Eggers 1977).

Intestinal contents of *Gila alvordensis* collected from Thousand Creek, Nevada, on 13 June 1978 and *G. alvordensis* collected from Serrano Pond, Oregon, on 6 August 1977 were compared to those of *G. boraxobius* col-

lected during the summer of 1978. Methods of collection and food habits analysis for populations of *G. alvordensis* were the same as those used for *G. boraxobius*.

#### STUDY AREA

Fish were collected from Borax (=Hot) Lake, Serrano Pond, and Thousand Creek, all in the Alvord Basin of southeastern Oregon and northwestern Nevada. The Alvord is an endorheic basin of semiarid climate, surrounded by fault-block mountain ranges. Borax Lake (T37S, R33E, Sec. 14, Harney County, Oregon) is a 4.1 ha natural lake that receives water from several thermal springs in the lake bottom. Water temperature in Borax Lake is typically 29–32 C, with extremes of 35 C or greater near spring sources and 17 C near the lake margin during winter. The lake is relatively shallow, with a soft, silty bottom interspersed with rocks and hard outcroppings. The water is transparent, and aquatic vegetation is limited to a few areas along the lake margin. Sodium is the principal cation, whereas bicarbonate, sulfate, and chloride are the major anions in Borax Lake (Mariner et al. 1974). Specific conductance of the water is 2410. Serrano Pond (T36S, R33E, Sec. 1, Harney County, Oregon) is a 0.1 ha reservoir that receives water from a cool spring approximately 60 m distant. Water temperature is usually 16–21 C during the summer. The bottom of this shallow pond is primarily silt. The water is turbid, and aquatic vegetation is abundant. Thousand Creek (collection site at T46N, R28E, Sec. 34, Humboldt County, Nevada) is a small, shallow stream rarely exceeding 2 m in width. The creek often becomes intermittent during summer months. Water temperature varies from 15–27 C during the summer, fluctuating rather closely with air temperature. The bottom is a silt and gravel mix. The water is turbid, and aquatic vegetation is moderately abundant.

#### RESULTS

##### Seasonal Variation in Foods Consumed

Twenty-four different food items were found in intestines of *Gila boraxobius* during

this study (Tables 1–4). Ten of the 24 food items were encountered in all seasons. Many food items fluctuated seasonally in occurrence; however, some insects, especially chironomid larvae, diatoms, and microcrustaceans, were of importance throughout the year. During the spring, algae, chironomid larvae, copepods, dipteran adults, and ostracods were the predominant food items (Table 1). Algae, which was composed almost wholly of diatoms, was the most frequently ingested food during the spring, occurring in over one-half of the intestines. Some of the diatoms were secondarily ingested with microcrustaceans; however, in some individuals diatoms accounted for 70–80 percent of the intestinal contents by volume. The high volume suggests that diatoms are not exclusively the result of secondary ingestion but are a preferred food item for most fish. The most common diatom observed in intestines was a benthic species, *Denticula thermalis*. *Navicula* sp., *Synedra* sp., *Achnanthes lanceolata*, and *A. minutissima* were observed in lesser numbers. Both *Achnanthes* species are benthic, whereas the *Navicula* and *Synedra* species could be benthic or planktonic forms. Adult dipterans accounted for the highest mean percent volume, nearly 20 percent, of all food items during spring. Several fish fed on dipteran adults exclusive of other foods. During May 1978 dipteran adults were heavily utilized, appearing in 19 of 23 intestines examined. During the summer, diatoms were less frequently encountered in intestines and comprised a smaller mean percent volume than in spring. Chironomid larvae, copepods, dipteran adults, and gastropods were the most important food items in summer (Table 2). *Gila boraxobius* utilized more terrestrial insects and spiders and fewer microcrustaceans and diatoms in summer than in spring. Terrestrial insects and spiders accounted for approximately 31 percent mean volume of foods consumed during summer compared to approximately 21 percent in spring. During autumn terrestrial insects, chironomid larvae, and diatoms were the principal food items (Table 3). In winter *Gila boraxobius* relied more heavily on autochthonous food items, utilizing primarily diatoms, ostracods, copepods, chironomid larvae and cladocerans (Table 4). Terrestrial insects,

which were of importance in spring, summer, and autumn, seldom appeared in intestines of *G. boraxobius* during winter, when they contributed only 2 percent mean volume. Food items consumed in autumn and winter were less diverse than in other seasons. Sixteen food items were observed in fish collected in autumn and winter, 20 food items during spring, and 21 during summer. Aquatic insects were important foods throughout the year, comprising mean volumes of approximately 19 percent, 23 percent, 16 percent, and 13 percent in spring, summer, autumn, and winter, respectively. The primary contributor to these high values were chironomid larvae, which consistently exhibited a high relative importance. Chironomid pupae and Odonata nymphs were also consumed throughout the year but were of much less

importance. Coleoptera larvae and aquatic Coleoptera adults were utilized to lesser degrees seasonally. The increased consumption of copepods, ostracods, and cladocerans in the winter was dramatic. These microcrustaceans comprised approximately 35 percent mean volume of intestines during winter, but only 16.5 percent, 12 percent and 4.5 percent in spring, summer, and autumn, respectively. Large amounts of inorganic debris were found in intestines throughout the year. This was probably ingested accidentally while the fish were feeding on bottom organisms. Many important foods in Borax Lake, such as insect larvae, gastropods, diatoms, and probably many small invertebrates, are benthic. Observations in Borax Lake and in aquaria show that *G. boraxobius* feeds primarily by rooting around in bottom material and pick-

TABLE 1. Contents of 71 intestines of *Gila boraxobius* collected during the spring of 1978. ND=no data.

Item ingested	Percent frequency of occurrence	Mean number per intestine	Mean percent volume	RI
Algae	56.14	ND	12.67	15.70
Gastropods	22.81	1.07	6.69	6.73
Gastropod eggs	0.00	0.00	0.00	0.00
Haplotaxid oligochaetes	1.75	0.11	0.32	0.47
Harpacticoid copepods	49.12	44.95	10.38	13.57
Ostracods	40.35	8.39	5.91	10.55
Cladocerans	15.79	0.21	0.17	3.64
Plant seeds	5.26	0.11	0.06	1.21
Higher plants	12.28	ND	1.72	3.19
Fish scales	3.51	0.11	0.04	0.81
Araneae	3.51	0.04	0.34	0.88
Insect eggs	10.53	12.26	2.15	2.89
Unidentified insects	26.32	ND	2.50	6.57
TERRESTRIAL INSECTS				
Collembola	0.00	0.00	0.00	0.00
Thysanoptera adults	3.51	0.04	0.39	0.89
Hemiptera adults	0.00	0.00	0.00	0.00
Coleoptera adults	1.75	0.02	0.21	0.45
Hymenoptera adults	3.51	0.04	0.49	0.91
Diptera adults	35.09	1.93	19.49	12.45
AQUATIC INSECTS				
Chironomid larvae	47.37	12.30	13.71	13.93
Chironomid pupae	7.02	0.14	2.32	2.13
Odonata nymphs	3.51	0.04	0.91	1.01
Elmids larvae	7.02	0.39	1.76	2.00
Coleoptera adults	0.00	0.00	0.00	0.00
INORGANIC DEBRIS				
	61.40	ND	17.48	—
		Total	99.71	

Mostly diatoms

Mostly *Planorbulla*, rarely *Physa*

Mostly terrestrial forms



ing up food items. However, if benthic food items are scarce, or if other foods are abundant, *G. boraxobius* will readily feed on materials drifting through water column or on the surface. Thus, during the summer some *G. boraxobius* readily switched to ingestion of terrestrial invertebrates. This resulted in the lowest mean percent volume of inorganic debris ingested for any season. The shoreline of Borax Lake provides habitat for many terrestrial invertebrates that can enter Borax Lake. Terrestrial invertebrates are scarce during winter, reducing the likelihood of their being a primary food source at that time.

*Gila boraxobius* is often a highly exploitive omnivore, feeding almost entirely on one food source. For example, examination of intestines of fish collected during May 1978 disclosed the following (percent volumes of

the food item are given in parentheses): one individual contained 32 gastropods (84 percent volume), a second fish contained 14 adult dipterans (98 percent volume), a third contained 775 copepods (79 percent volume), a fourth contained 340 first instar chironomid larvae (69 percent volume), and a fifth contained 485 insect eggs (64 percent volume)! Although the preceding is somewhat unusual, many fish were found with one food item dominating their intestinal contents.

Foods Consumed by  
Different Size Classes of Fish

To study the effect of fish size and age on foods consumed, we compared intestinal contents of juvenile and adult *Gila boraxobius*. Overall food habits of juveniles and adults were similar. Both consumed large amounts

TABLE 2. Contents of 70 intestines of *Gila boraxobius* collected during the summer of 1975. ND=no data.

Item ingested	Percent frequency of occurrence	Mean number per intestine	Mean percent volume	RI
Algae <sup>1</sup>	31.15	ND	6.42	7.42
Gastropods <sup>2</sup>	32.79	1.07	9.04	8.26
Gastropod eggs	1.64	0.66	1.56	0.63
Haplotaxid oligochaetes	1.64	0.08	0.30	0.38
Harpacticoid copepods	47.54	33.30	5.45	11.06
Ostracods	32.79	2.87	3.03	7.08
Cladocerans	8.20	0.38	0.31	1.68
Plant seeds	13.11	0.25	0.49	2.69
Higher plants	0.00	0.00	0.00	0.00
Fish scales	0.00	0.00	0.00	0.00
Araneae	14.75	0.25	3.21	3.55
Insect eggs	3.28	0.69	0.15	0.68
Unidentified insects	37.70	ND	4.50	8.34
TERRESTRIAL INSECTS				
Collembola	6.56	0.16	0.23	1.34
Thysanoptera adults	9.54	0.13	0.45	2.03
Hemiptera adults	0.00	0.00	0.00	0.00
Coleoptera adults	26.23	0.70	5.94	6.36
Hymenoptera adults	18.03	0.21	2.27	4.01
Diptera adults	39.34	1.62	14.31	10.60
AQUATIC INSECTS				
Chironomid larvae	57.38	4.10	13.79	11.06
Chironomid pupae	9.54	0.11	1.12	2.17
Odonata nymphs	1.64	0.03	0.49	0.42
Elmid larvae	11.48	0.23	0.85	2.44
Coleoptera adults	18.03	0.31	6.29	4.80
INORGANIC DEBRIS				
	54.10	ND	15.30	—
Total			95.50	

<sup>1</sup>Mostly diatoms  
<sup>2</sup>Mostly *Planorbulla*, rarely *Physa*  
Mostly terrestrial forms

of terrestrial insects in spring, summer, and autumn, and algae (mostly diatoms) and microcrustaceans in winter (Fig. 1). Aquatic insects, primarily chironomid larvae, were important to juveniles and adults throughout the year. Despite the overall similarity of food habits between juveniles and adults, some differences were noted. Elmid (Coleoptera) larvae were consumed almost exclusively by adults. Elmid larvae were found in intestines of 15 adults but only one juvenile. More terrestrial insects were consumed by juveniles than adults except during winter, when terrestrial insects were relatively unimportant to both groups. The relatively large size of many terrestrial insects, such as the commonly consumed muscoid fly adults, did not deter their ingestion by juvenile *Gila boraxobius*. Adults consumed more gastro-

pods than did juveniles during all seasons. Intestines of adults averaged 8.5 percent mean volume of gastropods during the year, whereas intestines of juveniles averaged 2.3 percent. Adults also consumed more diatoms than did juveniles. Increased relative consumption of diatoms by adults was primarily evident in summer and autumn, when adults consumed 9.3 percent and 6.9 percent mean volume of diatoms, respectively; however, juveniles consumed 0.1 percent and 1.3 percent mean volume, respectively. The small volume of gastropods and diatoms ingested by juveniles was compensated for by ingestion of large numbers of copepods. Intestines of juveniles averaged 13.4 percent mean volume of copepods during the year, whereas adults averaged 4.2 percent mean volume of copepods.

TABLE 3. Contents of 57 intestines of *Gila boraxobius* collected during the autumn of 1978. ND=no data.

Item ingested	Percent frequency of occurrence	Mean number per intestine	Mean percent volume	RI
Algae <sup>1</sup>	50.00	ND	5.03	12.63
Gastropods <sup>2</sup>	10.87	0.50	4.04	3.42
Gastropod eggs	0.00	0.00	0.00	0.00
Haplotaxid oligochaetes	0.00	0.00	0.00	0.00
Harpacticoid copepods	34.78	25.46	4.22	8.95
Ostracods	10.87	0.50	0.15	2.53
Cladocerans	0.00	0.00	0.00	0.00
Plant seeds	39.13	1.57	0.59	9.12
Higher plants	2.17	ND	0.07	0.51
Fish scales	0.00	0.00	0.00	0.00
Araneae	0.00	0.00	0.00	0.00
Insect eggs	2.17	0.04	0.04	0.51
Unidentified insects <sup>3</sup>	67.39	ND	19.54	19.95
TERRESTRIAL INSECTS				
Collembola	0.00	0.00	0.00	0.00
Thysanoptera adults	21.74	0.46	1.69	5.38
Hemiptera adults	13.04	0.22	2.55	3.58
Coleoptera adults	4.35	0.04	0.22	1.05
Hymenoptera adults	8.70	0.11	1.54	2.35
Diptera adults	19.56	0.22	3.52	5.30
AQUATIC INSECTS				
Chironomid larvae	71.74	5.43	12.00	19.22
Chironomid pupae	13.04	0.65	3.15	3.72
Odonata nymphs	6.52	0.07	1.29	1.79
Elmid larvae	0.00	0.00	0.00	0.00
Coleoptera adults	0.00	0.00	0.00	0.00
INORGANIC DEBRIS				
	86.96	ND	40.34	—
			Total	99.94

<sup>1</sup>Mostly diatoms

<sup>2</sup>Mostly *Planorbulla*, rarely *Physa*

<sup>3</sup>Mostly terrestrial forms

Diel Feeding Chronology

Feeding chronology and daily ration were determined by the relative weight of material ingested by *Gila boraxobius* collected during a 24-hour period in June 1979 (Fig. 2). The average weight of fish was 1.21 g. *Gila boraxobius* fed throughout the day with peak feeding activity shortly after sunset. Minimal feeding activities occurred after sunrise. An increase in feeding activity after sunset has been observed in *Gila bicolor* (Snyder 1917). The average weight of ingested material in intestines, as determined from 1800–1500 hours, was 2.32 percent of body weight. This average weight of ingested material ( $\bar{S}$ ) was used to determine the daily ration ( $R_T$ ) as follows:

$$R_T = 24\bar{S}\alpha = 24(2.32)(.2) = 11.14$$

By the above method we calculated that *G. boraxobius* ingested 11.14 percent of their body weight daily. This estimate is larger than most reported by researchers for other species. Brett (1979) summarized investigations made by various researchers who calculated daily rations that were typically 2–5 percent of body weight. Several studies have noted increased relative ration with increased temperature (e.g., Brett et al. 1969, Kinne 1960, Stauffer 1973) and with smaller fish size (e.g., Brett 1971, Brett and Shelbourn 1975, Elliott 1975). Brett (1979) reported that temperature and fish size were of greatest importance in determining ration size. The dwarf size of *G. boraxobius* and its

TABLE 4. Contents of 62 intestines of *Gila boraxobius* collected during the winter of 1978–79. ND = no data.

Item ingested	Percent frequency of occurrence	Mean number per intestine	Mean percent volume	RI
Algae <sup>1</sup>	94.44	ND	18.81	22.05
Gastropods <sup>2</sup>	18.52	0.54	3.88	4.36
Gastropod eggs	0.00	0.00	0.00	0.00
Haplotaxid oligochaetes	5.56	0.91	2.21	1.51
Harpacticoid copepods	75.93	16.44	9.96	16.72
Ostracods	77.78	21.65	20.58	19.15
Cladocerans	55.56	6.52	4.07	11.61
Plant seeds	3.70	0.04	0.02	0.72
Higher plants	5.56	ND	0.35	1.15
Fish scales	1.85	0.04	0.03	0.37
Araneae	0.00	0.00	0.00	0.00
Insect eggs	0.00	0.00	0.00	0.00
Unidentified insects <sup>3</sup>	9.26	ND	1.49	2.09
TERRESTRIAL INSECTS				
Collembola	1.85	0.04	0.33	0.42
Thysanoptera adults	0.00	0.00	0.00	0.00
Hemiptera adults	0.00	0.00	0.00	0.00
Coleoptera adults	0.00	0.00	0.00	0.00
Hymenoptera adults	0.00	0.00	0.00	0.00
Diptera adults	1.85	0.02	0.15	0.39
AQUATIC INSECTS				
Chironomid larvae	70.37	5.15	10.94	15.83
Chironomid pupae	1.85	0.02	0.22	0.40
Odonata nymphs	5.56	0.07	0.77	1.23
Elmud larvae	9.26	0.11	0.84	1.97
Coleoptera adults	0.00	0.00	0.00	0.00
INORGANIC DEBRIS				
	90.74	ND	25.37	—
Total			100.02	

<sup>1</sup>Mostly diatoms  
<sup>2</sup>Mostly *Planorbulla*, rarely *Physa*  
<sup>3</sup>Mostly terrestrial forms

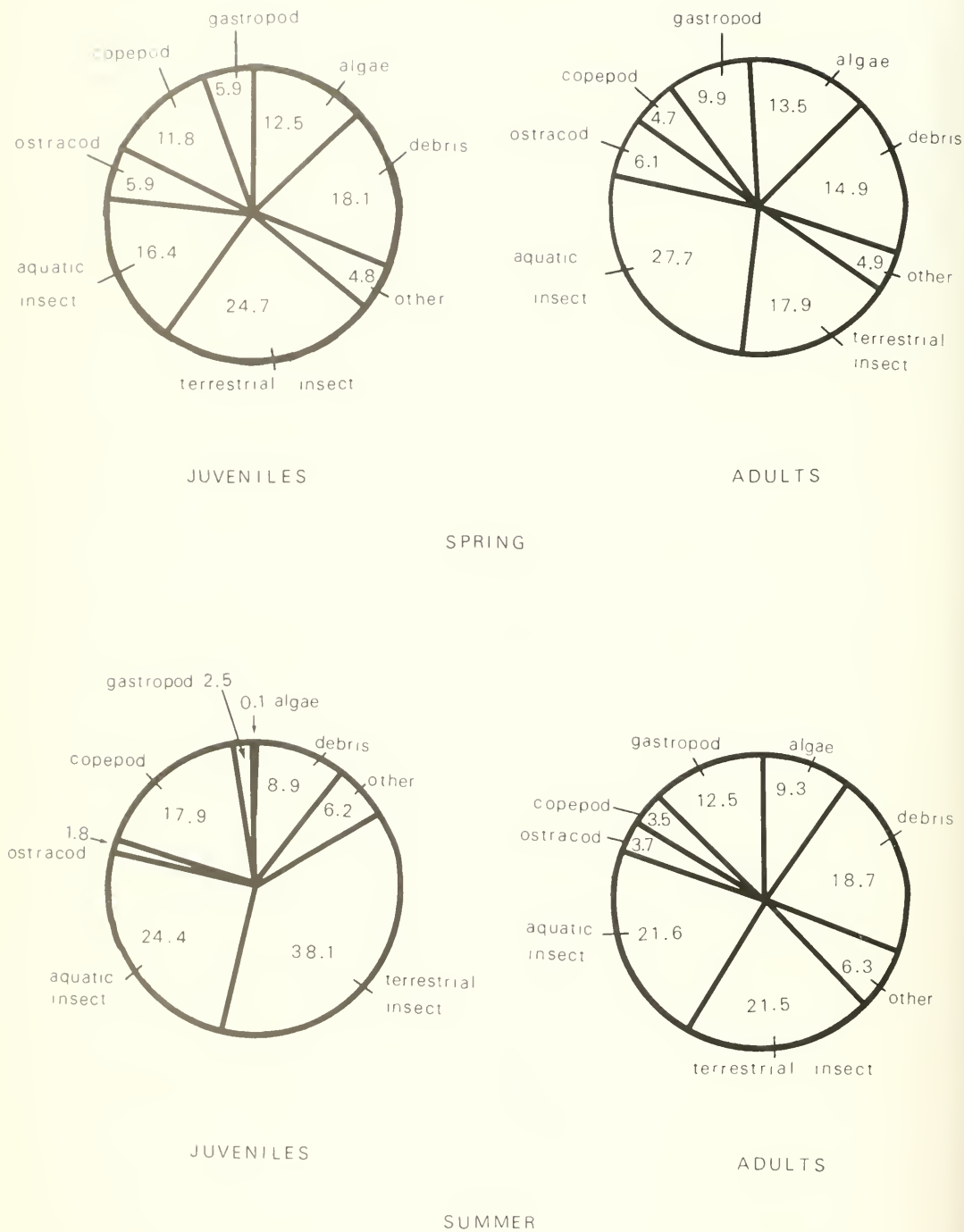


Fig. 1. Comparison of food habits between 125 juvenile and 132 adult *Gila boraxobius*. Mean percent volume of food items are given in circle.



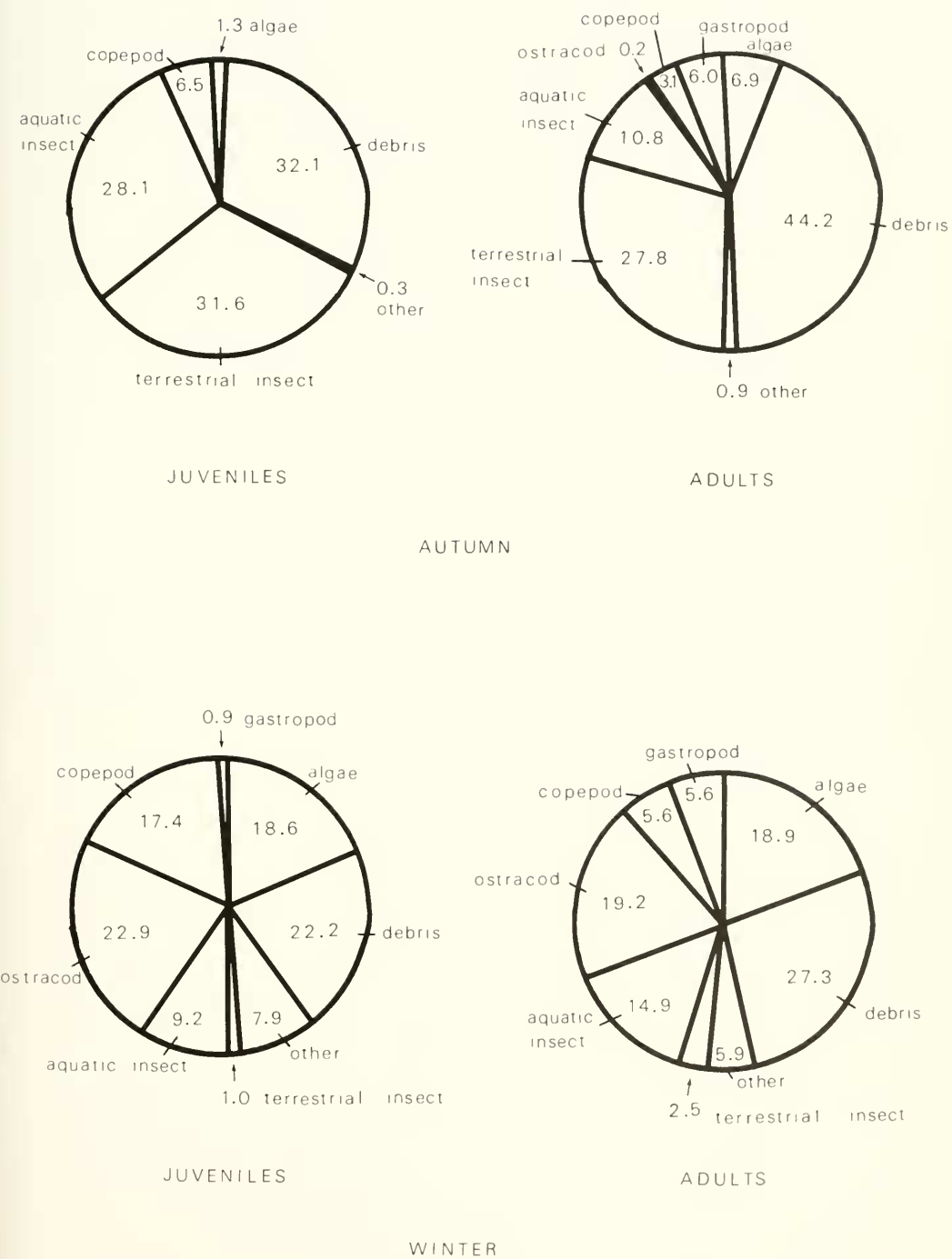


Fig. 1 continued.

habitation in thermal spring waters contributed to the large daily ration found in this species. Many researchers determined daily ration using prepared foods that were perhaps more nutritious than material ingested by *Gila boraxobius*, which included such undigestible items as insect exoskeletons, gastropod shells, and inorganic debris. The presence of large amounts of undigestible material increases  $\bar{S}$  because the fish must ingest a larger volume of material to get enough calories. This results in a larger daily ration than would be calculated if fish consumed only digestible foods.

#### Food Habits of *Gila alvordensis*

Ten food items were found in intestines of *Gila alvordensis* collected from Thousand Creek, Nevada, in June 1978 (Table 5). Of the ten food items, chironomid larvae, cladocerans, copepods, and ostracods were of greatest importance. Chironomid larvae occurred in all intestines examined and accounted for approximately 26 percent mean volume of intestines. Microcrustaceans comprised almost 45 percent mean volume of intestines. Diatoms accounted for 5 percent mean volume of intestines. No terrestrial insects were ingested by *G. alvordensis* from Thousand Creek.

Eleven food items were found in intestines of *Gila alvordensis* collected from Serrano Pond, Oregon, in August 1977 (Table 6). Of the eleven food items, chironomid larvae, diatoms, cladocerans, and ostracods were of greatest importance. Chironomid larvae occurred in over three-quarters of the intestines examined and accounted for approximately 50 percent mean volume of all intestines. Diatoms occurred in one-half of the intestines and accounted for almost 23 percent mean volume of all intestines. Microcrustaceans comprised approximately 17 percent mean volume of intestines. No intestines contained terrestrial insects. *Gila alvordensis* from Serrano Pond were highly opportunistic feeders. Eighty-nine percent of the fish from Serrano Pond with food in their intestines contained one item that accounted for more than 50 percent of their intestinal volume. Thirty-nine percent of fish contained one food item

that comprised 90 percent or more of intestinal volume. This exploitive feeding was focused on chironomid larvae, cladocerans, or algae. One intestine was exclusively filled with 2570 cladocerans. Such exploitive feeding was not noted in *Gila alvordensis* from Thousand Creek.

A comparison of foods of *Gila alvordensis* collected during June and August with foods of *Gila boraxobius* collected during the summer shows several differences. Terrestrial insects were important foods for *Gila boraxobius* during the summer but were absent from intestines of *Gila alvordensis*. *Gila boraxobius* also consumed larger quantities of other terrestrial foods, such as spiders and insect eggs, than did *G. alvordensis*. Intestines of *G. alvordensis* from Thousand Creek, and to a lesser extent those from Serrano Pond, contained much larger amounts of microcrustacea than did intestines of *G. boraxobius* during the summer. Diatoms were a major food item of fish in Serrano Pond during the summer, but not of fish in Thousand Creek or of *G. boraxobius*. *Gila boraxobius* consumed a larger number of food items than either population of *G. alvordensis*. This is due to the greater opportunism, including the use of terrestrial foods, exhibited by *G. boraxobius*. A larger sample size may also contribute to the greater diversity of foods utilized by *G. boraxobius*.

#### DISCUSSION

*Gila boraxobius* and *G. alvordensis* have tentatively been included with *G. bicolor* in the subgenus *Siphateles* (Hubbs and Miller 1972, Williams and Bond, in press). Although no life history information has previously been published for *G. boraxobius* or *G. alvordensis*, several researchers have examined food habits of *G. bicolor* and concluded that they are primarily opportunistic omnivores (Bird 1975, Cooper 1978, La Rivers 1962). However, differences in food habits between the coarse gill raker form, *G. b. obesa*, and the form with numerous, fine gill rakers, *G. b. pectinifer*, have been noted. In describing habits of the form with coarse gill rakers from Lake Tahoe, Miller (1951) found them to be primarily benthic feeders, with a diet

composed of 89 percent bottom organisms. Snyder (1917) noted that the form with coarse gill rakers collected from the littoral zone of Lake Tahoe fed on algae, other plant material, and insects. *Gila b. pectinifer* from Lake Tahoe, with its numerous gill rakers, fed almost exclusively on midwater microcrustacea (Miller 1951). La Rivers (1962) also reported that *G. b. pectinifer* contained many midwater foods in their intestines, primarily consuming diatoms and microcrustaceans.

Cooper (1978) reported that the form with numerous gill rakers (although he referred it to *G. b. obesa*) in Walker Lake, Nevada, fed mostly on zooplankton and filamentous algae. A population complex of *G. bicolor* in Eagle Lake, California, that included forms with both coarse and fine gill rakers fed on a variety of foods, including zooplankton, plant material, insect larvae, and surface insects (Kinsey 1954). There appears to be a definite correlation between gill raker morphology

TABLE 5. Contents of 21 intestines of *Gila alvordensis* collected 13 June 1978 from Thousand Creek, Nevada. ND=no data.

Item ingested	Percent frequency of occurrence	Mean number per intestine	Mean percent volume	RI
Diatoms	36.36	ND	5.00	7.91
Gastropods	9.09	0.09	0.36	1.81
Harpacticoid copepods	81.82	6.82	6.82	16.94
Ostracods	72.73	15.82	13.73	16.53
Cladocerans	90.91	27.73	24.23	22.01
Plant seeds	27.27	0.27	0.45	5.30
Araneae	9.09	0.09	0.55	1.84
AQUATIC INSECTS				
Chironomid larvae	100.00	16.73	25.78	24.04
Chironomid pupae	9.09	0.09	0.09	1.75
Coleoptera adults	9.09	0.09	0.68	1.87
INORGANIC DEBRIS				
	100.00	ND	20.95	—
Total			98.64	

TABLE 6. Contents of 20 intestines of *Gila alvordensis* collected 6 August 1977 from Serrano Pond, Oregon. ND=no data.

Item ingested	Percent frequency of occurrence	Mean number per intestine	Mean percent volume	RI
Diatoms	50.00	ND	22.94	18.16
Harpacticoid copepods	33.33	1.67	0.36	8.39
Ostracods	38.89	5.94	1.70	10.11
Cladocerans	55.56	253.28	15.34	17.65
Araneae	5.56	0.06	0.22	1.44
Insect eggs	5.56	0.06	0.05	1.40
Unidentified insects	5.56	ND	0.05	1.40
AQUATIC INSECTS				
Chironomid larvae	77.78	20.33	50.41	31.92
Chironomid pupae	22.22	0.33	2.96	6.27
Odonata nymphs	5.56	0.06	0.67	1.55
Ephemeroptera larvae	5.56	0.06	1.33	1.72
INORGANIC DEBRIS				
	55.56	ND	3.96	—
Total			99.99	

and food habits, those with coarse gill rakers ingesting more benthic food organisms and those with fine gill rakers ingesting more zooplankton. *Gila boraxobius* and *G. alvordensis* possess approximately 16 and 20 short gill rakers, respectively, agreeing closely with the gill raker morphology of *G. bicolor obesa* form. Although *G. boraxobius* typically feeds on benthic organisms, large amounts of diatoms, microcrustaceans, and terrestrial insects are ingested seasonally.

The ingestion of terrestrial insects by *Gila* is not common. However, several researchers have found that terrestrial insects comprised a small part of the diet of *Gila* (Cross 1978, Kimsey 1954, Moyle 1976, Sigler and Miller 1963). Terrestrial insects were the primary foods of *G. robusta* and *G. elegans* longer than 200 mm SL collected from the Green River (Vanicek and Kramer 1969). Smaller *G. robusta* and *G. elegans* contained predominantly aquatic insect larvae. Juvenile and adult *G. boraxobius* consumed large

quantities of terrestrial insects. Several researchers (Kimsey 1954, Miller 1951) have noted that as *Gila* grow, they switch to larger food items; however, at least one study (Graham 1961) found foods of different sized groups of *Gila* to be nearly identical. We found foods of juvenile and adult *G. boraxobius* to be very similar, except that adults exhibited a greater consumption of gastropods and diatoms, and juveniles consumed more copepods and terrestrial insects. The hard shells and, to a lesser extent, the relatively large size of gastropods probably contributed to juveniles avoiding them as a food source. Larger *Gila* ingest more algae than do smaller fish in studies by Moyle (1976) and Vanicek and Kramer (1969). Age II *Gila coerulea* feed predominantly on filamentous algae, whereas algae were entirely or practically absent from age I fish (Moyle 1976). Large adult *Gila* from the Green River consumed more algae than did smaller fish (Vanicek and Kramer 1969). Juvenile *G. borax-*

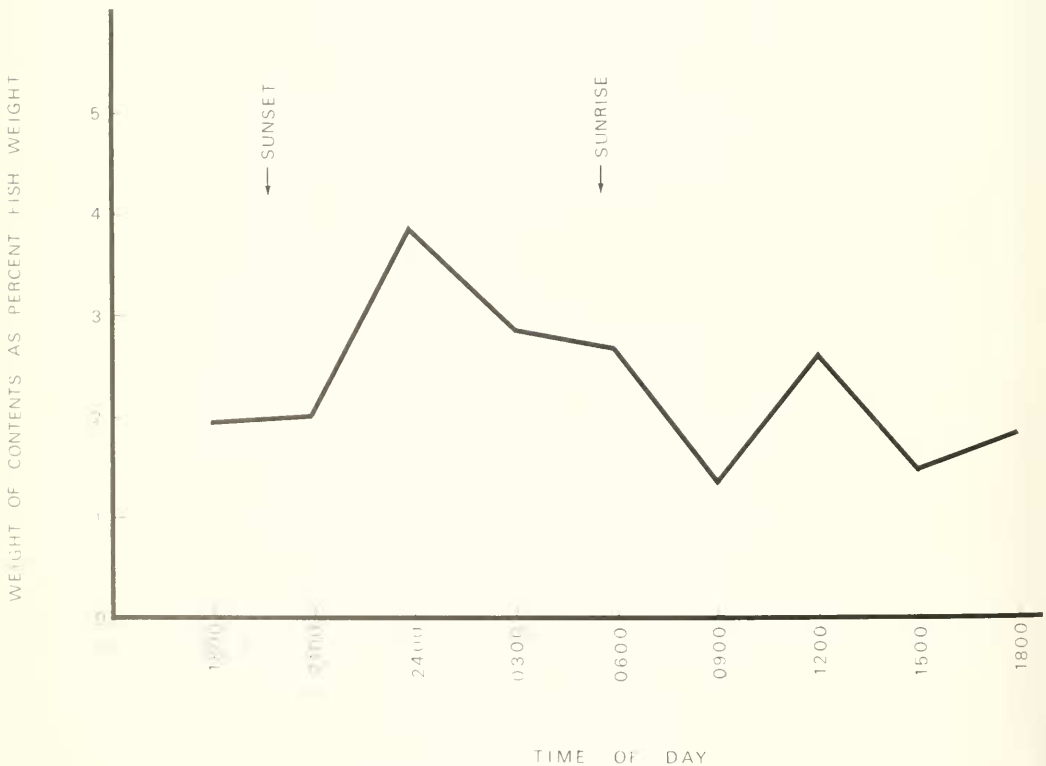


Fig. 2. Feeding chronology of *Gila boraxobius* on 5-6 June 1979. N = 72.

*obius* consumed more terrestrial insects than did the adults, except in winter, when small amounts of terrestrial insects were ingested by both groups. The reason for juveniles consuming large volumes of terrestrial insects is unknown; apparently the relatively large size of this food item is not a deterrent.

Both juvenile and adult *G. boraxobius* increased consumption of diatoms and microcrustaceans in winter. This probably indicates a scarcity of food items during the winter, as is reflected by finding 24 percent fewer food items in intestines during winter than in summer. A factor contributing to the winter scarcity of food items is a decrease in the availability of terrestrial foods, causing concentrated feeding on remaining food items. For example, the Devil's Hole pupfish, *Cyprinodon diabolis*, which inhabits a small thermal spring, dramatically increases ingestion of diatoms during winter due to a scarcity of preferred foods (Minckley and Deacon 1975). Although the amount of nutrition derived from consuming diatoms is unknown, we suspect that the large consumption of diatoms at certain times of the year by *G. boraxobius* would indicate that some nutritive value is gained. Arnold (1971) found that species of *Cyprinodon* derived oil droplets from ingested diatoms, thus extracting nutritive value. A similar mechanism could operate in *Gila boraxobius*.

Examination of summer foods of both *G. alvordensis* populations showed differences from the summer foods of *G. boraxobius*. During summer *Gila boraxobius* relied heavily on terrestrial food items, whereas populations of *G. alvordensis* consumed practically no terrestrial foods. Forty-three percent of food items consumed by *G. boraxobius* during the summer were of terrestrial origin. Surveys of potential food items in Borax Lake conducted at various times of the year found that all potential food items were utilized by *G. boraxobius* except some adult hemipteran and coleopteran insects that were probably too large to be ingested. Also, many hemipterans possess scent glands that render them unpalatable to predators.

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